THE EFFECTS OF BREED HETEROZYGOSITY ON KIDDING PERFORMANCE AND SUBSEQUENT REPRODUCTIVE SUCCESS IN GOATS.

A Thesis

Presented to the

Faculty of the College of Graduate Studies and Research

Angelo State University

In Partial Fulfillment of the

Requirements for the Degree

MASTER OF SCIENCE

by

ASHLEY BLAIR MCGINNIS

May 2021

Major: Animal Science

THE EFFECT OF BREED HETEROZYGOSITY ON KIDDING PERFORMANCE AND SUBSEQUENT REPRODUCTIVE IN GOATS.

by

ASHLEY BLAIR MCGINNIS

APPROVED:

Dr. Chase A. Runyan

Mrs. Audrey Meyer

Mr. Corey Owens

Dr. Kristen Lyons

May 2021

APPROVED:

Dr. Micheal W. Salisbury
Dean, College of Graduate Studies and Research

ACKNOWLEDGEMNTS

First, I would like to thank my committee members Dr. Chase A. Runyan, Mrs. Audrey Meyer, Mr. Corey Owens and Dr. Kristen Lyons for their time and guidance for helping me get through this. Additionally, I would like to give a big thank you to Mrs. Audrey Meyer for the many hours spent watching goats and helping me collect data. Furthermore, I would like to give thanks to the many people at the ASU Ranch including Cody Riddle, Deann Burson, Madonna Bullard, Clint Smith, Ian Witt, Ryan Kennedy, and Lance Culak for helping in various but important ways during the time of field work. A special thank you to my parents for encouraging me to continue to further my education.

ABSTRACT

The focus of this thesis was to investigate the effects of heterozygosity in goats on kidding performance and subsequent reproductive efficiency. The Boer and Spanish breeds are by far the most commonly used breeds in west Texas. Boer and Spanish cross breeding females were observed over a two-year breeding season. These females were bred to a Spanish billy to obtain F1, F2 and F3 offspring. The F1 generation is a true ½ Boer × ½ Spanish, F2 is ¾ Spanish × ¼ Boer and the F3 offspring are 5/8 Spanish × 3/8 Boer. The study used a semi-intensive management strategy to mimic producers in west Texas that rely heavily on dams yielding kids on their own. Kids were weaned at approximately 90 days of age and placed in weaning pens. After weaning, replacement females were exposed to a billy so that they may kid as yearlings. These young females were managed alongside the mature breeding females. Differences in heterozygosity were not statistically significant, but numbers showed that heterozygosity in doe populations could improve maternal characteristics and improve overall productivity in a goat herd.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Heterosis is a universally applied tool in any livestock production system achieved by capitalizing on a number of desirable traits from one or more breeds. Boer goats are known for their ability to have larger number of offspring, increased weaning weights, extreme growth rates, higher resistant to diseases, longevity, are not seasonal breeders and extra skeletal width in offspring. Spanish goats are more notorious for maternal capabilities such as higher twinning rates, breeding at an earlier age, longevity of production, adaptability, and kid survivability. The extra hardiness and survivability of Spanish goats is extremely sought after in low maintenance production systems. Implementing Boer genetics to increase weaning weights can be very influential in those same production scenarios. When retaining crossbred females, the preference to maintain growth traits from Boers while maintaining maternal abilities from Spanish bloodlines is ideal.

The primary objective of this study was to determine whether F1 or F2 progeny of females display different levels of reproductive traits (number weaned and weaning weights of kids). The second objective of this study was to observe variations of, if any, kids born of different breed and kids pastured.

Journal of Animal Science

LITERATURE REVIEW

The aspect that makes Boer dams unique is the fact that they are not created from one or two purebred dam species, but that they are a prototype of all dam breeds in South Africa to obtain the functional characteristics we observe today. Boers were brought over to North America from South Africa to combine genetics with the already existing Spanish breed of goats. Spanish goats, known as the land racers, were brought over in the 1500's with the conquests of the New World. Of the approximated five million meat goats in America, the majority are composed of Spanish meat dams (Malan et al., 2000). Though the native Spanish breed has adapted to the harsh environment of west Texas, improvement of the breed was inevitable. Having a better understanding of crossbred inheritance on reproduction performances in Boer and Spanish progenies will allow producers the knowledge to know what to look for and what to avoid when selecting replacement females. Selection of replacement females has the capacity to impact productivity of the mature flock for years to come.

Extensive studies have been conducted over Spanish and Boer crossbred dams revealing that age of estrus, ovulation rate, and age at anestrus are similar and the variation is very minimal, if present at all (Waldron et al., 1998). When considering number of kids born and weaning weight, age is a larger determining factor than breed of dams (Rhone et al., 2013). Age at first estrus in twin born dams has been proven to be four months sooner than single born dams (Waldron et al., 1998). Reproductive traits have been noted for offering low heritability in livestock and therefore offering little likelihood of change through genetics. Dam age plays an important role in reproductive traits. As a dam ages, she tends to increase her productivity level until she hits her optimum peak roughly around the fifth parturition; however, these increases in productivity are not observed until she hits her second parturition as she hits full maturity (Menezes et al., 2016). Females raising offspring as one year olds and two year olds are still experiencing growth themselves and do not peak their production level until growth has ceased for them. The amount of research conducted on yearling performance in goats is scarcely absent, but in sheep, it is widely present. Studies indicate that breeding ewes at 12 months of age has little effect, if any, on the long-term performance of the ewe, but breeding at 12 months of age is difficult due to the “shy” effect shown in ewe lambs when exposed to males (Kenyon et al., 2013). First-time ewe lambs also presented smaller litters and lower survival rates of offspring with the first parturition due to poor maternal behavior, demand for body growth in addition to growing a fetus in utero, and less intense oestrus periods (Kenyon et al., 2013). Females that breed at first exposure are expected to still be growing, lactating, and learning to care for offspring. This trio of tasks can pose a massive challenge to a successful first weaning. Age at first estrus assists producers in making management decisions regarding buck exposure and breeding timelines. If successful conception can be achieved during their first exposure followed by weaning of that offspring, there is potential to increase profitability and lifetime reproductive performance of those animals (Kenyon et al., 2013). Reproducing as first-year lambs comes with a lot of difficulties including shorter, less intense estrus periods, higher post-conception losses, less likely to seek and stand for rams being termed ‘shy’ breeders, increased loss of embryos, and conception rates of about 33 percent (Kenyon et al., 2013). Studies show that ewe lambs need to be placed with rams on at least three occasions to ensure 100 percent conception rates, indicating that rams prefer mature ewes over ewe lambs (Kenyon et al., 2013). Expanding the breeding window to ensure pregnancy in turn deceased offspring uniformity caused by the large span of birth dates.

The weight of kids and dams plays an important role in reproductive efficiency. They need to have the adequate amount of body weight and condition to conceive the pregnancy, carry that pregnancy to full term, have the kid or kids, and take care of those kids through weaning. Body condition of females going into the breeding season will have impacts on flock conception while BCS at parturition can impact dystocia issues such as ketosis and impact the longevity of the female’s lactation. Females that are thin prior to parturition and carrying multiple fetuses are more likely to experience ketosis near parturition. Boer dams’ genetic profile has been sought worldwide to improve growth rates in local dam population; they have been described as a large, fast bodyweight gaining breed; however, the characterization lacks sufficient research support (Browning et al., 2011). Several scientific researchers are conflicted on whether or not Boer dams are superior to other breeds. They performed on lower levels of reproductive efficiency if not equal to the Spanish and Kiko breeds (Rhone et al., 2013; Browning et al., 2011, Khanal et al., 2018). Spanish dams have proven to have higher survival rates and weaning weights of their offspring, but show similar characteristics to those of their crossbreed progenies. ½ Boer × ½ Spanish progenies obtained a greater number of kids born, heavier birth weights, and heavier breeding weights but lack in survival rate and weaning weight (Rhone et al., 2013). Looking deeper into the crossing and siring of Boer and Spanish. Browning (2011) crossed does with Boer sires and saw increased birth weights over straight bred local kids. Boer dams had increased body weight at kidding compared to Spanish dams at kidding. Rhone (2005) found that crossing Boer bucks with Spanish dams did not increase birth weights compared with straight bred Spanish mating. Boer dams seem to be unproductive in a semi-intensive production whereas for Spanish and Kiko, they thrive. There is a reduced reproductive efficiency in Boer dams compared with Spanish does under moderate to low levels of nutrient resources (Browning et al., 2011)

Survivability of offspring and the mothering ability is just as pertinent in a dam production operation as reproductive efficiency. Breeding programs have a significant necessity for improving kid survivability and including this trait as a section criterion for their breeding females (Zeleke et al., 2020). Early weaning for kids could also be a contributing factor to the survivability of those kids and understanding that stunted growth and other issues could also play into those numbers as well. From pasture to weaning is the most vulnerable and the most growing a kid will do in its lifetime, which suggests that interventions need to be targeted during the pre-weaning period (Todd et al., 2019). While on pasture, goat kids are potentially subjected to disease, predation, weather and many other situation that may not be monitored by producers on a daily basis. Implementing practices that can minimize or alleviate some of these situations can certainly improve survivability of kids on pasture. Dams need to be able to conceive and provide for kids until weaning. Boer kids were reported to have at least 30 percent mortality rate compared to Spanish and Kiko (Rhone 2013). As value in goats' increases, the understanding of how to manage them becomes ever more important and pertinent for production operations.

The proposed study furthers the knowledge of Boer and Spanish goats by comparing Boer, ½ Spanish x ½ Boer (F1), and ¾ Spanish x ¼ Boer (F2) females and their reproductive performance. The variation in crossbreed gives a microscopic look at the differences, if any, into the Boer and Spanish breeds. The underlying knowledge will come from first, second, and multiple years of age to compare more data and understand more about them.

MATERIALS AND METHODS

Goats utilized for this study where maintained at the Angelo State University Management, Instruction and Research Center (MIR) located in San Angelo, TX over a one-and-a-half-year span. The goats' grazed native pasture prior to and during the study; in addition, they were provided ad libitum water and complete trace mineral. Open Boer dams (n=17), ½ Boer x ½ Spanish (n=100, F1 generation), and ¾ Boer x ¼ Spanish (n=57, F2 generation) were bred to a full-blooded Spanish billy, from August to September of 2019. The full-blood Spanish billy was placed in a pasture with the open dams of different bloodlines for approximately 45 days. One month after removal of the billy, the dams where evaluated for conception using ultrasonography (ALOKA SSD 500) and blood draw on yearlings to confirm open (Circle H laboratory in Dalhart, Texas). Upon confirmation of pregnancy, dams were put back out on pasture for the first four months of pregnancy.

The last month of pregnancy, January 2020, dams were housed in feeding pens and separated into different pens according to their generation (Boer, F1 or F2) and observed for daily collection of kidding information. All dams received a complete ration formulated for pregnant females in addition to ad libitum water (Table 1). All dams received 2 mL of Bar Vac CD-T Cattle, Sheep & Goat Vaccine as a subcutaneous injection prior to kidding. The dams were observed twice daily and date of birth (DOB), born as (twin, triplets, and singles), and gender were collected on offspring. Kids that were rejected by dams and hand raised were excluded from data collection but counted against dam weaning numbers and pasture data. All offspring received an ear tag for identification that corresponds to dam ear tag number and number of siblings.

Table 1. Ration fed to animals while in pens. (kg as fed)

Ingredients	**Weight (kg)**
Corn/Distiller's Dried Grain Mix	454.55
Cotton Seed Hulls	272.73
Alfalfa Pellets	131.82
Molasses	36.36
ASU Pre-Mix	22.73

After all had given birth, dams and kids were released on grazing pasture to remain until disbudding and a second round of 2 mL of Bar Vac CD-T Cattle, Sheep & Goat Vaccine as a subcutaneous injection for all kids approximately a month and a half after birth, then returned back to pasture. At weaning, kids were removed from dams and weaning weights and number weaned were collected as well as body weight of dams weaning kids. All kids were sorted by gender and placed in pens with ad libitum feed and water. Dams where evaluated and those that need to be culled for lameness, age, disposition etc. were sorted. F1 and F2 progenies were retained and utilized in the following year's research to analyze and compare first, second, and multiple year reproductive traits from those dams. F3 offspring were removed from the study. All dams were released out on native pasture until breeding season.

For the fall of 2020 breeding season, an F2 billy (¾ Spanish × ¼ Boer) was turned in F1 with (½ Spanish × ½ Boer) nannies and an F1 billy (½ Spanish × ½ Boer) was put out with F2 nannies (¾ Spanish × ¼ Boer), all (5/8 Spanish × 3/8 Boer) offspring. Boers at this time were removed from the breeding group because of culling issues and not utilized for the second round of data collection. All F1 and F2 breeding females were exposed to a billies for

45 days. The same protocol was followed for the 2020 breeding season and 2021 kidding season, as stated above in the previous year.

Frequency tables were created using the Proc Freq models of SAS with the Fisher's option being used to detect differences in frequency distribution in the binary data analysis. The Proc mixed procedures of SAS were used to analyze continuous variables using multiple effects and interactions. Doe weight at the time of weaning is used frequently in this analysis as a covariate. The Pdiff option of SAS was used to detect differences in the Least Squares Means with a $P \leq 0.05$ level of significance being considered different. While $P > 0.05$ and $P < 0.1$ being considered as tendencies.

RESULTS

This dataset spans one and a half years and was analyzed accordingly. Not all analysis contains 2 years of completed data but when possible and appropriate, the analysis was combined with year serving as a random effect in all mixed model procedures. Considering year 1 only, the Chi-square analysis of the distribution tables of the number of kids born by breed type (Table 2) and the number of kids weaned by breed type (Table 3) did not present significant differences (*P* = 0.37 and *P* = 0.29), respectively.

Table 2. Number of kids born by breed (P=0.3677).

	1	2+	Total
½ Spanish× ½ Boer	16	28	44
	36.36% Row	63.64%	
	64.0% Column	60.87%	
¾ Spanish×¼ Boer	5	5	10
	50.0% Row	50.00%	
	20.0% Column	10.87%	
Boer	4	13	17
	23.53%	76.47%	
	16.0%	28.26%	
Total	25	46	71

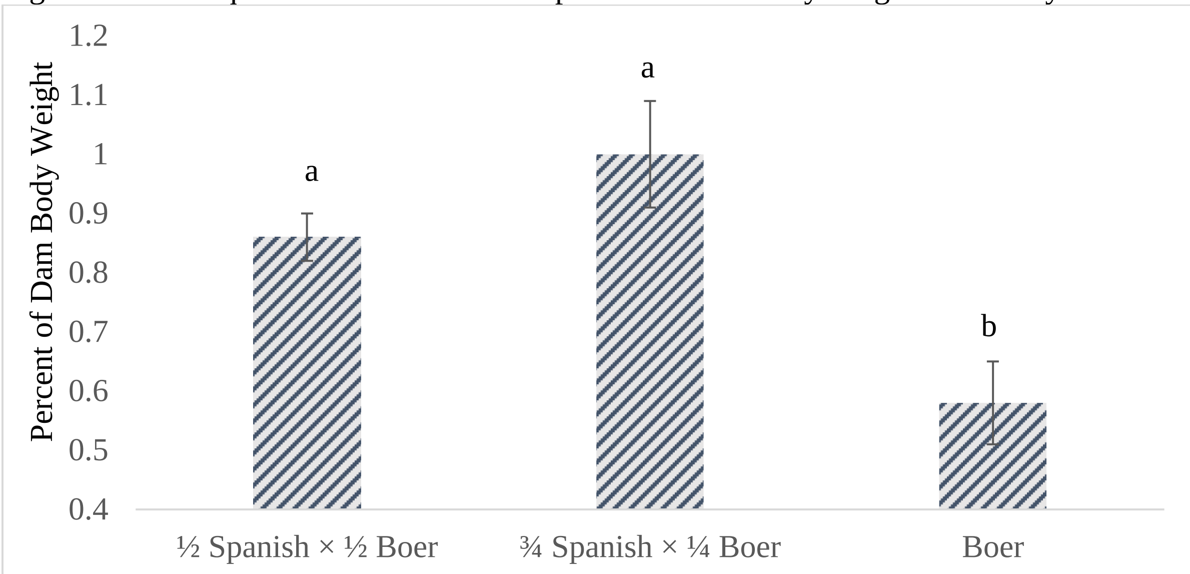
Interestingly however, while the Boer dams have a higher percentage of multiparous kids born, the Boer breed type also had the highest percentage of dams that failed to wean a kid.

Table 3. Number of kids weaned by breed (P=0.2903).

	0	1	2+	Total
½ Spanish × ½ Boer	2 4.55% Row 40.0% Column	21 47.73% 67.74%	21 47.73% 61.76%	44
¾ Spanish×¼ Boer	0 0% Row 0% Column	5 50.0% 16.13%	5 50.0% 14.71%	10
Boer	3 18.75% Row 60.0% Column	5 31.25% 16.13%	8 50.0% 23.53%	16
Total	5	31	34	70

The amount of kids that did not come back from pasture for the Boers (18.75%) in Table 3, is significantly higher and similar issues pertaining to mothering ability and survivability were observed in other reports (Rhone et al., 2013; Browning et al., 2011, Khanal et al., 2018). This is especially problematic when the data was tabulated as a weaning percentage ((Number of kids born ÷ number of kids weaned) × 100) and could therefore be analyzed in a mixed model analysis. Differences in the weaning percentage (P < 0.001) were due to breed type and presented in Figure 1.

Figure 1. Least Squares Means estimate of percent of dam body weight weaned by dam breed



[a,b] Differing superscripts *P*-values differ by ($P \leq 0.05$)

This data implies that increasing heterozygosity in dam breed is preferable to Boer dams. Furthermore, while we do not have a full Spanish group in this analysis, increasing the Spanish breed type to ½ or more would be recommended to improve weaning percentages in kid groups. Corresponding research from Khanal (2018) showed Boer crosses with Kiko and Spanish exhibited higher fertility and weaning rates than full Boer dams, but did not differ from the other full blooded breeds of Kiko and Spanish.

Data contained in Table 4 and Table 5 were collected over a two-year span of kidding seasons. These tables analyze the number of kids born by breed (Table 4) and subsequently, the number of kids raised until they could be moved to a pasture managed system (Table 5). It is important to acknowledge that the Boer dams were culled heavily, and therefore, the number of Boer observations is limited as compared to the number of ½ Spanish × ½ Boer and ¾ Spanish × ¼ Boer dams in this dataset.

Table 4. Number of kids born by breeds (P<.0001).

	0	1	2+	Total
½ Spanish × ½ Boer	19	31	50	100
	19.0% Row	31.0%	50.0%	
	42.22% Column	56.36%	67.57%	
¾ Spanish×¼ Boer	26	20	11	57
	45.61% Row	35.09%	19.30%	
	57.78% Column	36.36%	14.86%	
Boer	0	4	13	17
	0% Row0%	23.53%	76.47%	
	Column	7.27%	17.57%	
Total	45	55	74	174

The first year we did observe a higher number of loses between birth to pasture compared to our second year loses between birth to pasture. Presuming that an increase in intensive management decisions about culling played a small part.

Table 5. Number of kids put out on pasture by breed (P=0.0002).

	0	1	2+	Total
	22	35	43	100
½ Spanish× ½ Boer	22.0% Row	35.00%	43.0%	
	44.90% Column	59.32%	65.15%	
	26	20	11	57
¾ Spanish×¼ Boer	45.61% Row	35.09%	19.30%	
	53.06% Column	33.90%	16.67%	
	1	4	12	17
Boer	5.88% Row	23.53%	70.59%	
	2.04% Column	6.78%	18.18%	
Total	49	59	66	174

Breaking down the two years' worth of data from the kids born by dam breed (Table 4) with Table 6, Table 7, and Table 8. ½ Spanish× ½ Boer have 6% loss of kids (Table 6) and Boer dams have 7.69% loss of kids (Table 8). Though ½ Spanish × ½ Boer are still below Boer, the amount of kids produced by ½ Spanish × ½ Boer (n=100) and Boer (17) shows the variation in those percentages.

Table 6. Number of ½ Spanish× ½ Boer kids born by number of kids pastured (P < 0.0001).

Pastured (Row) → Born (Column) ↓	0	1	2+	Total
0	19 100.0% Row 86.36% Column	0 0.00% 0.00%	0 0.00% 0.00%	19
1	0 0.00% Row 0.00% Column	31 100.0% 88.57%	0 0.00% 0.00%	31
2+	3 6.00% Row 13.64% Column	4 8.00% 11.43%	43 86.00% 100.0%	50
Total	22	35	43	100

Table 7. Number of ¾ Spanish× ¼ kids born by number of kids pastured (P< 0.0011)

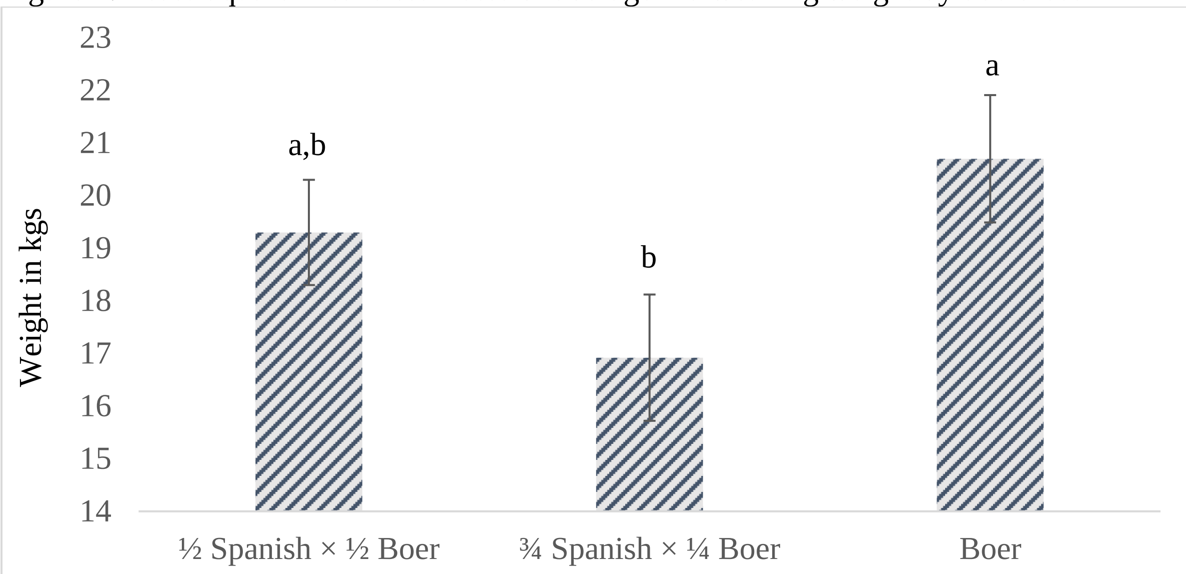
Pastured (Row) → Born (Column) ↓	0	1	2+	Total
0	26 100.0% Row 100.0% Column	0 0.00% 0.00%	0 0.00% 0.00%	26
1	0 0.00% Row 0.00% Column	20 100.0% 100.0%	0 0.00% 0.00%	20
2+	0 0.00% Row 0.00% Column	0 0.00% 0.00%	11 100.0% 100.0%	11
Total	26	20	11	57

Table 8. Number of Boer kids born by number of kids pastured (P < 0.0001).

Pastured (Row) → Born (Column) ↓	0	1	2+	Total
0	0 0.00%Row 0.00% Column	0 0.00% 0.00%	0 0.00% 0.00%	0
1	0 0.00% Row 0.00% Column	4 100.0% 100.0%	0 0.00% 0.00%	4
2+	1 7.69% Row 100.00% Column	0 0.00% 0.00%	12 92.31% 100.0%	13
Total	1	4	12	17

Dam breed type, as a main effect, was a source of variation in the average kid weight at weaning analysis and is presented in Figure 2.

Figure 2. Least Square Means estimates of average kid weaning weight by doe breed

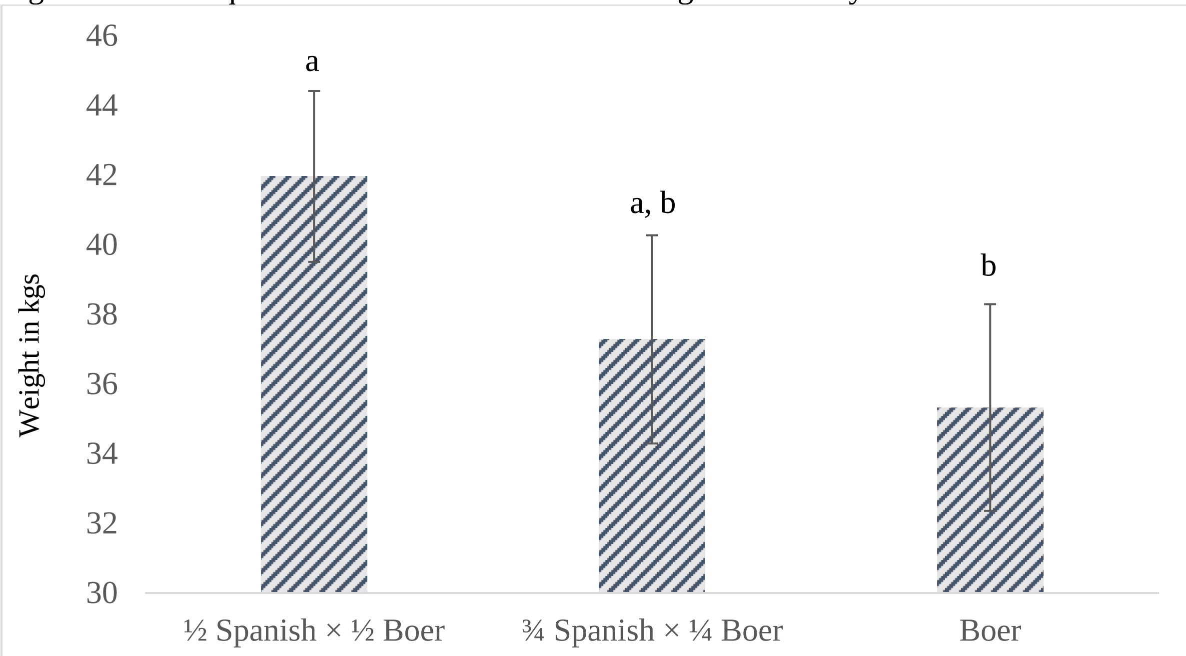


[a,b] Differing superscripts *P*-values differ by ($P \leq 0.05$)

Because the progenies that were produced by the full blood Boer dams, would exhibit the highest percentage of heterozygosity, it is expected that the Boer progeny should therefore express the most growth at weaning due to hybrid vigor advantages when mated with predominately Spanish bucks in this data. The ½ Spanish × ½ Boer progenies were not statically different from the ¾ Spanish × ¼ Boer or the Boer progeny. The Boer dams produced kids that were significantly heavier than the ¾ Spanish × ¼ Boer dams ($P \leq 0.05$). It is important to acknowledge that the individual dams' weight was included in this model to account for the variation in dam size across the breed types in the analysis. This covariate was a significant source of variation ($P < 0.0001$) and so further analysis was warranted to consider the relationship of dam weight and kid weight at weaning. This investigation lead to a calculated column of the average kid weight weaned as a percentage of the dams own body weight at weaning ((average weight of kids at weaning ÷ weight of dam when kids are weaned) × 100). Numerically, Boer were 36% ± 2% of their mother's own body weight at weaning time. While the ¾ Spanish× ¼ Boer dam produced kids were 30% ± 2% and the ½ Spanish × ½ Boer were 33% ± 2%. The analysis was important to consider in this data even though the Boer produced kids were heavier than the ¾ Spanish × ¼ Boer. The variation in the dams' size does not imply disproportionally heavier progeny at weaning.

When considering the number of kids born, number of kids processed to pasture, and the number of kids that are weaned, a much clearer pattern emerges regarding mothering ability in regards to heterozygosity in the breed type of the dam. In Figure 3, the least square means of the total weight weaned across the dam breed type is presented.

Figure 3. Least Squares Means estimates of total weight weaned by doe breed



a,b Differing superscripts *P*-values differ by ($P \leq 0.05$)

The ½ Spanish × ½ Boer dams weaned the highest total weight at 41.96 ± 2.45 kg which was significantly more that the Boer produced kids (35.33 ± 2.97 kg) but not significantly greater than the ¾ Spanish × ¼ Boer produced kids (37.28 ± 2.99 kg). This data suggests that producers may be able to enhance their overall weight of kids weaned by increasing heterozygosity of dams to half-blood status and thereby increase revenue and improve operational efficiency by maintaining a population of dams that are more likely to produce, rear, and wean a greater number of lighter weight kids.

As a generalized analysis of fertility and subsequent kidding rates, across breeds in the second year of this data only, frequency tables were used to evaluate the associative nature of yearling fertility and kidding rates with second year kidding rates (Table 9).

Table 9. Comparing dams' number of kids born by one- and two-year old's (P=0.1)

Yr. 2 (Row) → Yr. 1 (Column) ↓	0	1	2+	Total
0	11 50.0% Row 73.33% Column	6 27.27% 40.00%	5 22.73% 41.67%	22
1	3 23.08% Row 20.00% Column	7 53.85% 46.67%	3 23.08% 25.0%	13
2+	1 14.29% Row 6.67% Column	2 28.57% 13.33%	4 57.14% 33.33%	7
Total	15	15	12	42

In these data, the distribution of the number of dams that failed to breed as yearlings suggests that only 50% will rebreed and kid as a 2-yr old dam. Additionally, 73.33% of all females that failed the kid as a 2-year old also failed to breed as yearlings. Therefore, a culling strategy that includes strict kidding rates as yearlings is warranted to reduce the number of dams that fail to kid as a 2-year old. This implication suggests that a producer could increase reproductive efficiency while also conserving resources to only dams that kid as yearlings.

Table 10 and Table 11 are presented in this report to further illustrate the favorable relationships of dam that kid as yearlings and subsequent prolificacy as 2 year olds. While differences were not detected in either table from the χ^2 analysis. The biological impact and practical application of this data merits acknowledgement.

Table 10. ½ Spanish× ½ Boer conception rate as one- and two-year old's (P=0.2).

Yr. 2 (Row) → Yr. 1 (Column) ↓	No	Yes	Total
No	5 50.00% Row 71.43% Column	5 50.00% 38.46%	10
Yes	2 20.0% Row 28.57% Column	8 80.0% 61.54%	10
Total	7	13	20

Table 11. ¾ Spanish× ¼ Boer conception rate as one- and two-year old's (P=0.1)

Yr. 2 (Row) → Yr. 1 (Column) ↓	No	Yes	Total
No	6 50.00% Row 75.0% Column	6 50.00% 42.86%	12
Yes	2 20.0% Row 25.0% Column	8 80.00% 57.14%	10
Total	8	14	22

IMPLICATIONS

Results of these data imply that full Boer females seem to be limited in maternal strengths, which is confirmed in other research papers that have reported similar observations. Due to the semi-extensive nature of the production schemes in this report, the full Boer dams seem to be limited in overall productivity, which is otherwise realized in more intensive management operations. While full Boer dams did generate additional weaning weight from the kids that did survive, full Boers tended to wean fewer kids as compared to ½ Spanish × ½ Boer. In the production scheme utilized by the Angelo State University Management Instruction and Research Center, the ½ Spanish × ½ Boer dams are the ideal crossbreed to keep and utilize for a semi-intensive operation. This data also vividly illustrates that keeping first kidding yearlings, that fail to conceive as yearlings and allowing them a second chance as two year olds, is not an advisable decision.

LITERATURE CITED

Browning, R, Jr., and M. L. Leite-Browning. September 2011. Birth to weaning kid traits from a complete diallel of Boer, Kiko, and Spanish meat goat breeds semi-intensively managed on humid subtropical pasture. *Journal of Animal Science.* Volume 89, Issue 9, Page 2696-2707.

Browning, R., Jr., M.L. Leite-Browning, and M. Byars, Jr. March 2011. Reproductive and health traits among Boer, Kiko, and Spanish meat goat does under humid, subtropical pasture conditions of the southeastern United States. *Journal of Animal Science.* Volume 89, Issue 3, Page 648-660

Kenyon, P.R., Thompson, A.N., and Morris, S. T. 2013. Breeding ewe lambs successfully to improve lifetime performance. *Small Ruminant Research. Page 118.*

Khanal, Piush, Maria L. Leite Browning, and Richard Browning Jr. January 2018. Influence of crossbreeding on meat goat does fitness when comparing Boer F1 with base breeds in the Southeastern United States. *Journal of Animal Science*. Volume 97, Issue 1. Page 78-89.

Malan, S. W. 2000. The improved Boer goat. Journal of Animal Science. Volume 36, Issue 2 Pages 165-170.

Menezes, L.M., Sousa, W.H., E.P. Cavalcanti-Filho, and L.T. Gama. March. 2016. Genetic Parameters for reproduction and growth traits in Boer goats in Brazil. *Small Ruminant Research.* Pages 247-256.

Rhone, J.A. 2005. Estimation of reproductive, production, and progeny growth differences among F1 Boer-Spanish and Spanish females. MSc Thesis. Texas A&M University, College Station.

Rhone, J.A., D.F. Waldron and A.D. Herring. 2013. Performance of Boer-Spanish and Spanish Goats in Texas I: Body weights, fertility, prolificacy, and number of kids weaned. *Journal of Animal Science*, Volume 91, Issue 10, Pages 4679-4683.

Todd, C.G., B. Bruce, L. Deeming, and G. Zobel. 2019. Short Communication: Survival of Replacement Kids from Birth to Mating on commercial Dairy Goat Farms in New Zealand. *Journal of Dairy Science*. Volume 102, Pages 9382-9388

Waldron, D.F., T.D. Willingham, P.V. Thompson, R.G. Eckhoff and B.J. May. April 1998. Age at first Estrus, Ovulation rate, and age at anestrus in pubertal Boer×Spanish and Spanish Does. *Small Ruminant Res.* Volume 31, Issue 2, Pages 173-176.

Zeleke, Tesema, Kefyalew Alemayehu, Damitie Kebede, Tasfaye Getachew, Belay Deribe, Mengistie Taye, Mekonnen Tilahun, Alemu Kefale, Asres Zegeye, Negus Belayneh, and Liuel Yizengaw. 2020. Genetic analysis of survival potential of Boer × Central Highland goats under semi-intensive management. Small Ruminant Research. Volume 193.

Appendix : Institutional Care and Use Committee Approval 2020 – 103

ANGELO STATE UNIVERSITY

College of Graduate Studies & Research

Institutional Animal Care & Use Committee

March 30, 2020

Audrey Zoeller
Department of Agriculture
Angelo State University
San Angelo, TX 76909

Your proposed project titled, "The effects of breed heterozygosity on kidding performance, twinning rate and subsequent reproductive success in goats" was reviewed by Angelo State University's Institutional Animal Care and Use Committee (IACUC) in accordance with the regulations set forth in the Animal Welfare Act and P.L. 99-158.

This protocol was approved for three years, effective March 30, 2020 and it expires three years from this date; however, an annual review and progress report form (www.angelo.edu/content/files/22583-iacuc-annual-review-progressreport) for this project is due on August 15 of each year. If the study will continue beyond three years, you must submit a request for continuation before the current protocol expires.

The protocol number for your approved project is 2020-103. Please include this number in the subject line of in all future communications with the IACUC regarding the protocol.

Sincerely,

Chase Runyan, Ph.D.
Co-Chair, Institutional Animal Care and Use Committee

VITA

Ashley Blair McGinnis was born to Blair and Kelly McGinnis in Lubbock, Texas where she lived with her brother William McGinnis until moving overseas. In 2012, Ashley graduated from Snyder High School in Snyder, Texas. Ashley received her Bachelor of Science in Animal Science emphasis in Reproduction from Angelo State University in May of 2019. In May of 2021, Ashley expects to receive her Master of Science in Animal Science.